



Shaw Air Force Base

Home of the 9th Air Force, 20th Fighter Wing

Initial Report...FY'02 CERL PEM Demonstration Program
LOGANEnergy Corp.
Shaw Air Force Base PEM Project
Residence of Lt. Col. Jackson,
June 11, 2003

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Introduction

Fuel Cells convert the chemical energy of a fuel into useable electric and thermal energy without an intermediate combustion or mechanical process. In that respect, they are similar to batteries. However, unlike batteries, fuel cells oxidize externally supplied fuel and therefore do not need recharging. Ever since National Aeronautics and Space Administration (NASA) adopted fuel cell power for the Apollo Space program, American industry has been fascinated by the prospects for their use on earth as well.

When integrated with a fuel processor and a solid-state power conditioner, the power system becomes one that produces clean, quiet and reliable electric power and heat. Several manufacturers are currently hard at work to translate the basic technology into consumer products. As advances in PEM technology and mass production converge to introduce competitively costs systems into the marketplace, many are betting that small scale fuel cell generators will soon be ready to tackle thousands of residential and small scale commercial power applications. These new appliances will be packaged energy systems providing both heat and electricity that will be able to operate with or without the local utility grid.

Until recently, however, the promise of fuel cell technology has been slow to advance beyond a narrow beachhead commonly referred to as the "early adopter" marketplace. Broader market appeal has been constrained by fits, false starts and premature expectations raised by eager manufacturers; but also high prices, skepticism, and not a little resistance by parochial interests have all restricted the opportunity. Notwithstanding, during the decade of the 1990s, the UTC PC25C Fuel Cell program, largely assisted by a significant investment by DOD, gradually established a solid record of achievement and customer satisfaction at numerous US locations and around the world. Installations sites included military hospitals, commercial buildings, banks, food processing facilities, data processing centers, police stations, and airports.

While many of these "early adopters" hosted pure technology demonstration projects, the industry gained valuable experience and knowledge because of them. More recently, however, customers have warmed to the proposition that fuel cells have real performance advantages in various combined heat and critical power applications (CHP). Perhaps their attitudes and business practices may be adjusting to accommodate an uncertain energy landscape. Clearly, many energy providers are scrambling

to maintain their market base, others are floundering, and still others are stalking new opportunity. Nevertheless, they are all discovering that informed consumers have gained new leverage through the power of choice. Increasingly, newspaper articles, periodicals and other media outlets are scoring direct hits with stories about fuel cells. Policy makers are out front raising expectations of a cleaner highly efficient fuel cell/hydrogen based economy of the future. The signals are clear. Initiative and momentum are driving a rapidly maturing fuel cell industry.

Certainly one reason is because fuel cell technology represents, perhaps, the most exciting and innovative development in the energy industry today. In some ways the technology is maturing more rapidly and markets are developing more quickly than the supporting infrastructure, codes and standards are able to accommodate. However, as technology demonstrations increasingly give way to CHP fuel cell installations that provide practical solutions to demanding consumer requirements, such roadblocks should get resolved as consumer and utility interests find common ground. For example, in most applications, large-scale fuel cell installations may off-load significant power resources during critical grid demand intervals, serving utility interests, while providing "hot" back-up for mission essential loads in commercial and even residential applications. Additionally, they may also provide thermal Btus for heating and cooling loads-demonstrating the dual benefits of enhancing grid stability and promoting energy conservation.

At the small scale and residential end of the fuel cell spectrum, the opportunity is just as promising for the rapid expansion of distributed power generation. Conceivably, thousands of 3kW to 5kW CHP fuel cells in homes and small businesses across the country could within several years displace hundreds of MWhs of electricity and millions of thermal Btus with clean, efficient and reliable energy service. If this occurs, it could have a dramatic impact on both the energy industry, and on the nation's economy and security. Consumers, not utilities, could begin displacing environmentally disruptive generation methods, thereby forcing changes in the industry. As providers of grid resources, they may one day collectively enhance grid stability in many areas, boosting efficiency and conservation norms, having a decided impact on the evolution of national energy policy.

Against this backdrop, the US Army Corps of Engineers, Construction Engineering Research Lab (CERL) has contracted with LOGANEnergy through its FY'02 PEM Demonstration Program to engage a progressive fuel cell energy strategy to inform future DOD policy and planning. Broadly speaking, this engagement directs LOGAN to purchase and install residential and small-scale fuel cell power plants, and then test and evaluate their performance in widespread applications at selected military installations. Three seemingly incongruous events make this program very timely. They are (a) the complexities and perplexities of utility deregulation juxtaposed with, (b) base utility privatization programs, and (c) the nascent interest in distributed

generation / CHP technologies that promise more efficient utilization of resources.

If the fuel cell industry can capitalize on these conditions, it will have a rich market opportunity, but it will have to deliver energy services and benefits that are immediate, site specific, cost effective, energy efficient, and certifiably green!

In order to test and evaluate the state of PEM fuel cell technology against these challenges, LOGANEnergy Corporation will demonstrate over the course of a year a PEM small scale fuel cell at Shaw AFB, Sumter, SC; home of the 9th Air Force, 20th Fighter Wing. The project will be guided by an operations plan that will direct the installation, testing, evaluation and reporting on the performance of the unit. The objectives of the plan include;

1. Evaluating installation methods in order to help standardize safe and cost effective installation practices,
2. Evaluating "out of the box" reliability and interoperability with existing facility electrical and mechanical systems / infrastructure,
3. Evaluating actual PEM operating characteristics as compared to manufacturer representations,
4. Measuring the cost of operating a PEM unit under real market conditions,
5. Measuring, collecting and analyzing operating data including, total load hours, availability, kW production, fuel consumption, water consumption, forced outages, serviceability, and manufacturer's support.
6. Introducing PEM technology, power distribution and energy efficiency to DOD and local stakeholders in the community.

The project will be led by LOGANEnergy and supported by Plug Power and Energy Signature Associates.

Shaw AFB PEM Site Selection and Installation

In February 2002 LOGAN contacted Mr. Gregory Skaggs, Shaw AFB Utilities Engineer, to discuss whether Shaw might have an interest in hosting a CERL Small Scale Residential PEM Fuel Cell project. As a result of the conversation, LOGAN visited Shaw in May 2002 to tour the base and make a preliminary PEM evaluation. During the visit, LOGAN investigated a number of possible installation sites including the air traffic control tower, the airman's mess hall and Building 1610, which housed the 77th Tactical Fighter Squadron. Following the tour, LOGAN and Mr. Skaggs reached consensus that the 77th Squadron Headquarters building would be the best choice. In June 2003, LOGAN proposed Shaw as a candidate site in its FY'02 PEM fuel cell demonstration program submittal to CERL.

In December 2002 LOGAN received notice that Shaw would be awarded a PEM demonstration program. In mid-January 2003 LOGAN scheduled the kick-off meeting at Shaw hosted by Greg Skaggs. Others attending the meeting included Dr. Mike Binder and Mr. Nick Josifik with CERL, and Sam Logan and Mike Harvell of LOGANEnergy. At the meeting, Mr. Skaggs indicated that the 77th Fighter Squadron had deployed to Iraq and the

Squadron Headquarters' building was empty. After further discussion and a visit to Lt. Col. Jeffrey Jackson's residence, the meeting reached a consensus to install the fuel cell there. Lt. Col. Jackson is the commander of the Shaw Civil engineering Squadron.

Figure 1 and Figure 2 are photos of the fuel cell on its pad at Lt. Col. Jackson's residence. The photo at left shows a wide-angle view of the site with the Plug unit on its pad adjacent



to Lt. Col. Jackson's residence. The natural gas interface was conveniently located next to the pad. Electrical interface was also convenient to the fuel cell pad. The unit appears to be somewhat obtrusive and a little out of character with a typical residential neighborhood, but has not caused concern to neighbors. Note the utility transformer in the foreground above left for relative scale.



In Figure 2, at right, a closer view of the installation shows the natural gas service interface on the rear wall, and the electrical panel, meter box and generator disconnect mounted on the fence to the right of the unit. The fuel

cell was rigged onto the pad with assistance of Air Force personnel using a base forklift.

The installation at Lt. Col. Jackson's residence offered stimulating new challenges and complexities not encountered in previous installations. For example, both the equipment room containing the hot water heater and the closet containing the electrical distribution panel were located within the interior spaces of the house. This necessitated routing electrical conduit and thermal recovering piping through the attic crawl space. It also necessitated the use of seamless water tubing for the thermal piping runs to preclude the risk of overhead plumbing leaks during the project. Since the water heater closet was too small to install a companion indirect heater, and too far from the fuel cell to house other system components, new ideas were needed to integrate the fuel cell with the residence

Figures 3 & 4 below are photos of a new exterior weatherproof equipment shed, behind the Plug Power fuel cell that offered the solution for the installation issues encountered at the site. The small metal panel structure houses the thermal recovery water heater, the reverse osmosis filtration system, the circulating pump and the instrumentation devices that monitor and log performance including the Btu meter assembly and the pulse data logger.



Figure 3



Figure 4

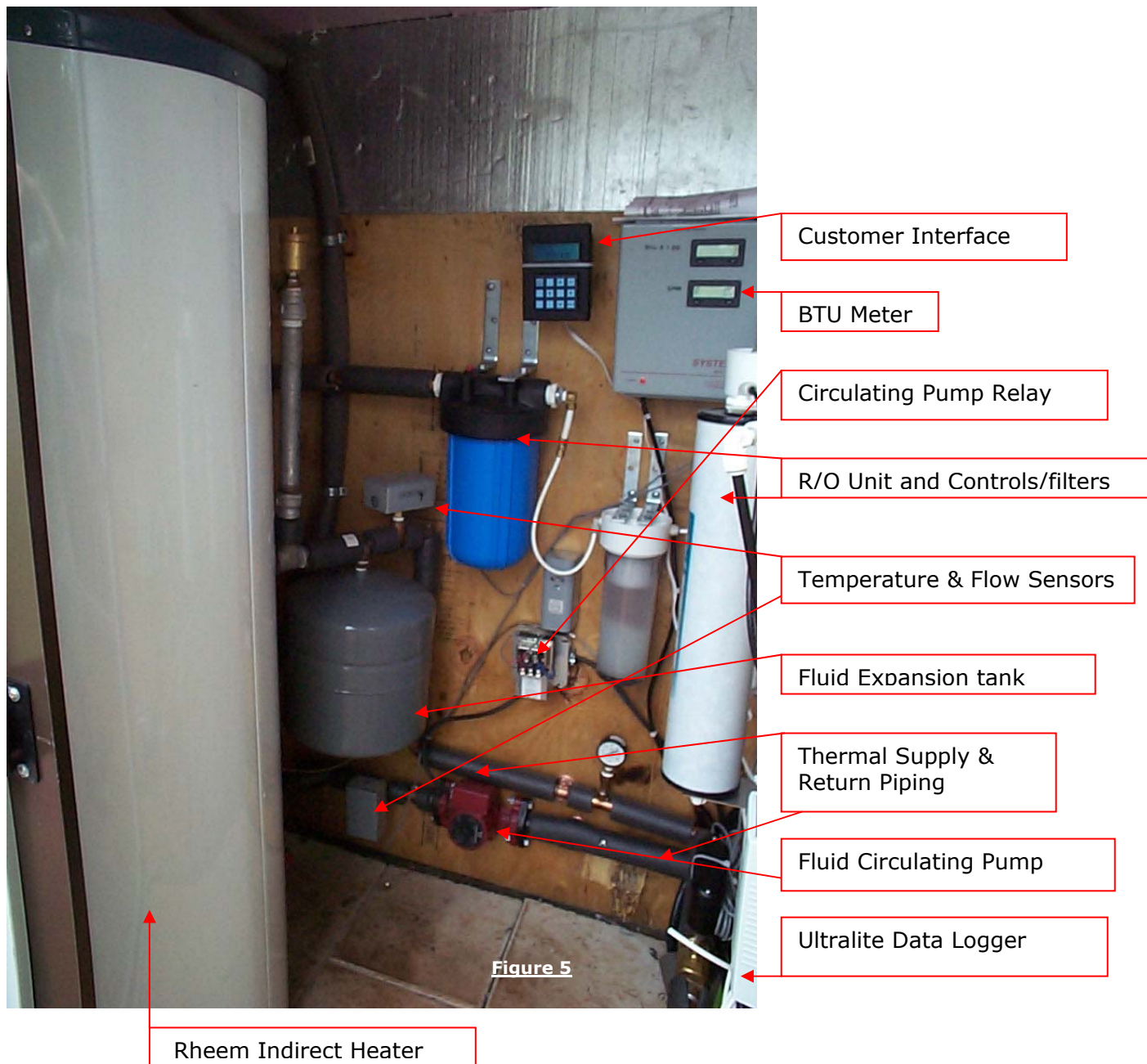
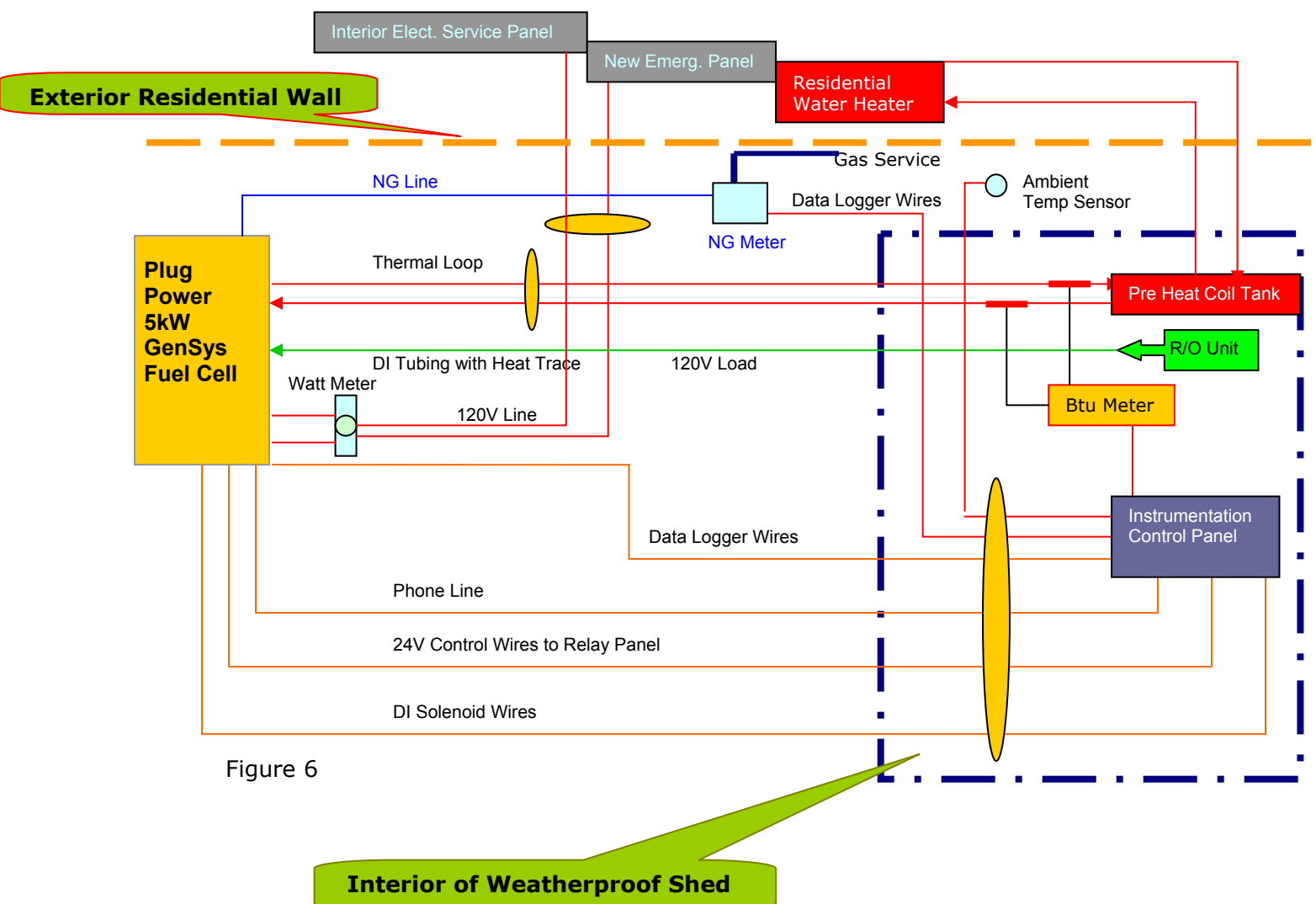


Figure 5, above, is a picture of the interior layout of the equipment installed in the weatherproof shed adjacent to Lt. Col. Johnson's residence. The individual components are described in red boxes above with arrows pointing to each. The thermal recovery system using the Rheem Indirect Heater, pictured above, is designed to capture waste heat from the fuel cell and store

it in the form of hot water, which may then be transferred to the residential water heater, located in a central closet within the house, upon demand. The R/O unit provides deionized water for cell stack hydration, reformate production and cooling. The BTU meter provides a continuous readout of heat transferred into the thermal recovery system. The data logger receives 30-second interval pulse inputs from the natural gas meter, the wattmeter, and the BTU meter, and records the date and time of these events.

Shaw AFB Installation Line Diagram

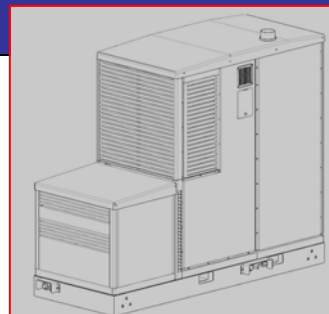
Lt. Col. Jackson's Family Residence.



GenSys5C Product Specifications

Plug Power Fuel Cell System

The GenSys5C is a 5kWAC on-site power generation system fueled by natural gas. Designed to be connected to the existing power grid, the 5C is a clean and efficient source of power.



Specifications

Physical	Size (L X W X H):	84 1/2" X 32" X 68 1/4"
Performance	Power rating: Power set points: Voltage: Power Quality: Emissions:	5kW continuous 2.5kW, 4kW, 5kW 120/240 VAC @ 60Hz IEEE 519 NO _x < 5ppm SO _x < 1ppm Noise < 70 dBA @ 1meter
Operating Conditions	Temperature: Elevation: Installation: Electrical Connection: Fuel:	0°F to 104°F 0 to 750 feet Outdoor/CHP GC/GI Natural Gas
Certifications	Power Generation: Power Conditioning: Electromagnetic Compliance:	CSA International UL FCC Class B

Dimensions

Length	84 inches
Width	32 inches
Height	68 1/4 inches

Operating Requirements

Fuel Type	Natural Gas
Temperature	0 degrees F to 104 degrees F

Outputs

Power Output	5kW
Voltage	120/240 VAC @ 60Hz
Noise	< 70 dBA@ 1 meter

Certifications

CSA International	Fuel Cell System
UL	Power Conditioning Module

Figure 7

Installation Application

Figure 6, above, diagrams the fuel cell installation with utility interfaces including, power, water and natural gas. Figure 7, above, lists the specifications of the Plug Power GenSys5C PEM technology demonstration fuel cell chosen for this site. Natural gas service for the fuel cell was already conveniently located adjacent to the pad. The electrical conduit runs to the interior residential load panels from the fuel cell were approximately 60 feet. The Reverse Osmosis/DI water tubing run that provides filtered process water to the power plant is approximately 10 feet distance, and the thermal recovery piping runs between the fuel cell and the new storage tank are also approximately 10 feet. The installed hot water tank is a 74-gallon Rheem heat coil unit that supplies hot water to the existing residential hot water heater. Piping runs between the two tanks are approximately 60 feet. Fuel Cell waste heat should be adequate to meet the domestic hot water demand of the Jackson residence. Figure 6 also indicates the location of an Onicon BTU meter on the thermal recovery system that will record the waste heat utilization by the Jackson family. Data logging will be accomplished with an Ultralite Logger also indicated in Figure 6 above.

The fuel cell inverter has a power output of 110/120 VAC at 60 Hz, matching the home's power distribution panel with its connected loads at 110/120 VAC. The installation includes both a grid parallel and a grid independent configuration as indicated in Figure 6. The unit provides stand-by power to a new 100amp critical circuit panel that serves plug loads in the kitchen area of the home. A two-pole wattmeter, seen in Figure 1 monitors both the grid parallel line and the grid independent load to record fuel cell power delivered to both the existing panel and the new critical load panel installed in the Jackson residence.

A new natural gas meter, illustrated in Figure 6 above, provides an independent verification of fuel flow, and a regulator at the fuel cell gas inlet maintains the correct operating pressure at 14 inches water column.

A phone line connection with the fuel cell modem provides communications with Plug Power and LOGAN customer support functions.

Permitting

LOGAN contacted the South Carolina Department of Health and Environmental Control to inquire of the need to apply for an air quality permit to operate the fuel cell. As was the case with the Ft. Jackson South Carolina installation, no permit was required. The Shaw public utilities division provided a digging permit. As the utility distribution wires are the property of Shaw AFB, no grid parallel generation permits were needed to operate the fuel cell

Start-up and Commissioning

The first start occurred on May 5, 2003. Prior to starting the unit the items covered in Figure 8, below, were completed. During the week of June 9, 2003, LOGAN's fuel cell systems technician will continue to test and monitor the unit in accordance with the factory recommended procedures listed in Figure 8 and 9, below. At this time, operations testing and tuning of the fuel cell's electrical and mechanical systems continues to insure smooth and reliable performance. It is anticipated that the unit will be declared operational by June 16, 2003.

Service incidents and facility calls will be reported on the sample Service Call Report form listed below as Figure 10.

An initial Economic Analysis of the Shaw AFB RESSDEM installation appears in Figure 11 below.

A site map in Figure 12 below indicates the location of the fuel cell installation at Shaw.

Installation Check List

TASK	SIGN	DATE	TIME(hrs)
Batteries Installed			
Stack Installed			
Stack Coolant Installed			
Air Purged from Stack Coolant			
Radiator Coolant Installed			
Air Purged from Radiator Coolant			
J3 Cable Installed			
J3 Cable Wiring Tested			
Inverter Power Cable Installed			
Inverter Power Polarity Correct			
RS 232 /Modem Cable Installed			
DI Solenoid Cable Installed with Diode			
Natural Gas Pipe Installed			
DI Water / Heat Trace Installed			
Drain Tubing Installed			

Figure 8

Commissioning Check List

TASK	SIGN	DATE	TIME (hrs)
Controls Powered Up and Communication OK			
SARC Name Correct			
Start-Up Initiated			
Coolant Leak Checked			
Flammable Gas Leak Checked			
Data Logging to Central Computer			
System Run for 8 Hours with No Failures			

Figure 9



SERVICE CALL REPORT	SYSTEM INFORMATION		
System Serial #: _____	Date _____		
Purpose of Service Call: <input type="checkbox"/> Repair <input type="checkbox"/> Maintenance <input type="checkbox"/> ECN (Check all that apply)			
Date/Time shutdown _____ _____	Date Time		
MAINTENANCE / REPAIR INFORMATION			
<i>Service Tech Name:</i> _____			
<i>Travel Man-hours:</i> _____			
<i>Troubleshooting Manhrs:</i> _____			
<i>Repair Man-hours:</i> _____			
<i>Spare Part Delay Time:</i> _____			
<i>Work Performed:</i> _____ _____			
<i>Technician</i> _____			
<i>Comments:</i> _____ _____ _____			
FAILURE REPORT SUMMARY			
Date	Description of Problem	Rpt #	Initials

Figure 10

LOGANEnergy Corp.

FY' 02 RESSDEM

Shaw AFB PEM Fuel Cell Economic Analysis

Estimated Project Utility Rates

1) Water (per 1,000 gallons)	\$1.69
2) Electricity (per KWH)	\$0.0651
3) Natural gas (per MCF)	\$5.25

Estimated First Cost

Plug Power 5 kW SU-1	\$65,000
Shipping	\$1,800
Installation electrical	\$4,200
Installation mechanical	\$5,000
Watt Meter, Instrumentation	\$3,150
Site Prep, labor materials	\$925
Technical Supervision	\$8,500
Total	\$88,575

Assume Five Year Simple Payback

\$17,715

Forecast Operating Expenses	Volume	\$/Hr	\$/ Yr
Natural Gas			
Mcf/hr @ 2.5kW	0.032838	\$0.17	\$1,359
Water			
Gals/Yr	4918		<u>\$8.31</u>

Add Total Annual Operating Costs

\$1,368

Total Annual Costs (Ammortization + Expenses)

\$19,083

Economic Summary

Forecast Annual kWh	19710	
Annual Cost of Operating Power Plant	\$0.0694	kWh
Credit Annual Thermal Recovery	-0.016489	kWh
Project Net Operating Cost	\$0.0529	kWh
Ammount Available for Financing	\$0.0122	kWh
Add 5 Yr Ammortization Cost / kWh	\$0.8988	kWh

Current Demo Program Cost Assuming 5 Yr Simple Payback

\$0.9682 kWh

****NOTE****Does not include allowance for cell stack life cycle costs or service over 5 year economic senario

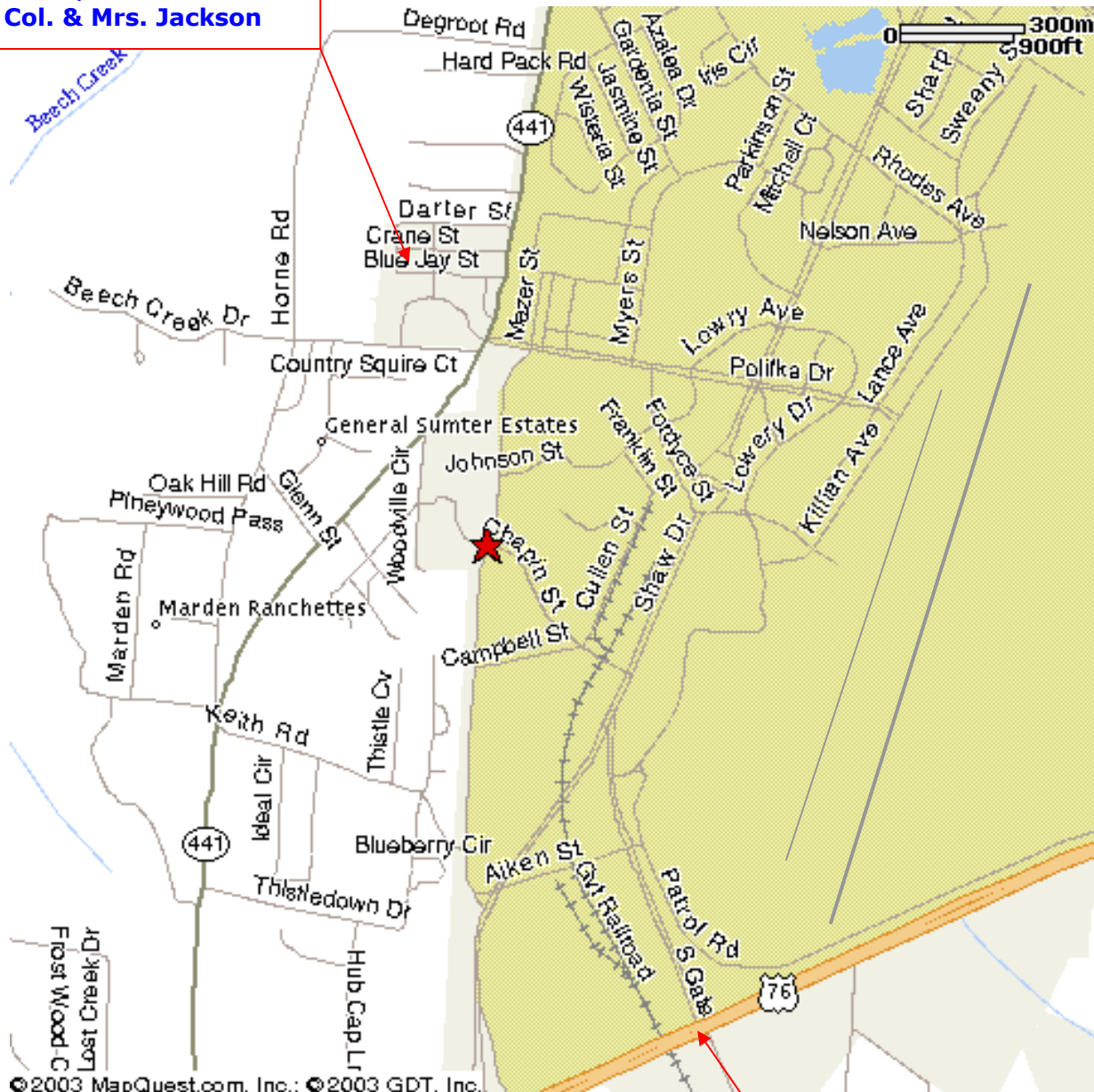
Figure 11

Project Contacts

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Shaw AFB, SC

**PEM Site, Residence of
Lt. Col. & Mrs. Jackson**



South Gate Entrance